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Research Article

Studies on environmental impact assessment of wastewater pit in Izombe flow station, South-Eastern Nigeria

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Abstract

Three (3) wells were sunk with a hand – operated light cable percussion rig to maximum depth of 15.00 to 21.00m. The static water levels recorded after drilling for each well were 8.00m for borehole 1 (BH 1), 4.40m for BH 2, and 5.00m for BH 3. The soil stratigraphy reveals a uniform correlation in the three (3) boreholes of medium to very coarse grained sand and gravelly sand. The lower layers are coarser, so that there appears to be a downward coarseness of the grains. There is also a downward decrease in the shade of brownish colour. In BH 1, there is an upper stratum of dark brown, medium grained, friable sand to a depth of about 9.00m. This is underlain by light brown, very coarse grained, gravelly sand. BH 2 and BH3 display similar profiles of overlying dark brown, medium grained, friable sands of about 3.0m in thickness. This is followed by light brown, coarse grained sands to depths of about 15.00m. Light brown, very coarse grained, gravelly sands extend from this depth to the maximum drilled depth of 21.00m. Results also reveal that the soil is non-plastic and fall within the soil classification group of SP under the Unified Soil Classification System. Permeability tests of the samples are moderately high values as expected for the sandy soils and range from 7.83 x 10^{-1}cm/s to 8.92 x 10^{-1}cm/s. The hydraulic gradient between BH 1 and BH 3 is about 6% or 1m in 16m (1:16) while that between BH 1 and BH 2 is about 7% or 1m in 14m (1:14). Since the hydraulic gradient between BH 1 and BH 2 is slightly higher, more rapid effluent discharge is expected towards BH 1. This may explain the higher concentration of crude oil contamination of the groundwater, particularly within the region of the waste pit.

Keywords: Soil, groundwater, Environmental Impact Assessment, Contamination, Wastewater

INTRODUCTION

Environmental Impact Assessment (EIA) studies ensures that the effects of projects on the environment as well as on natural resources are properly evaluated and mitigated where necessary (Nwankwoala et al., 2009). The uncertainties associated with soil and water degradation caused by pollution and hydrological impacts requires improved hydro-geotechnical data analysis in order to determine local groundwater flow direction and how pollutants reaching groundwater migrates along the flow paths (Rodriguez, 2006; Hasfurther and Turner, 2008).

In this study, the physical properties of the soil samples were examined to obtain parameters used as indices of the infiltration capacity of the soils at the site. Therefore, this paper presents an integrated assessment of the hydrological and geotechnical aspects of Izombe flow station, for better understanding of their importance in Environmental Impact Assessment (EIA) studies.

The Study Area

The study area, Izombe (Figure 1) is located in Imo State, Nigeria. The geomorphologic setting of the site is sub-horizontal with a gentle gradient seaward. It is located within the coastal plain sands of the Tertiary Benin Formation and consists of considerable thickness of red earthy coarse to medium sand with subordinate silt and clay lenses derived from the underlying strata. The Benin Formation consists predominantly of about 90% freshwater continental sands and gravel which are massive, porous with intercalations of clay/shale beds (Allen, 1965).

According to Etu – Efeotor (1981), Etu-Efeotor and Akpokodje (1990), Offodile (2002), Udom et al. (2002), Olobaniyi and Owoyemi (2006), the Benin Formation is highly permeable, prolific, productive and is the most extensively tapped aquifer in the Niger Delta. All the boreholes in the study area are drilled into it.

The aquifers in the area obtain steady recharge through direct precipitation where annual rainfall is as high as 2000 – 2400mm. The water infiltrates through the highly permeable sands of the Benin Formation to recharge the aquifers.

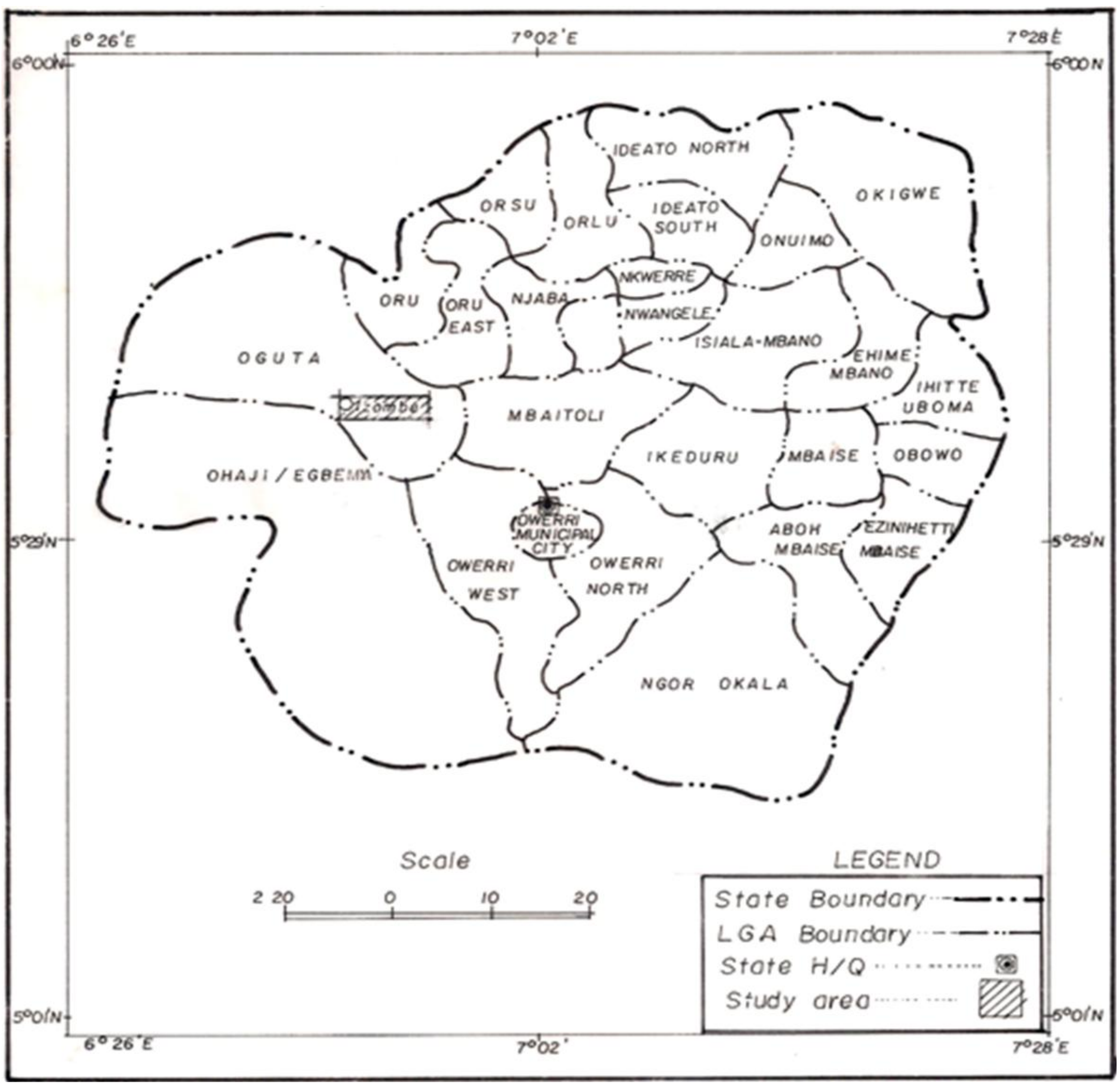

Figure 1. Map of Imo State Showing the Study Area

METHODS OF INVESTIGATION

Borehole Drilling

Drilling of water boreholes for water level monitoring and sub-soil analysis was carried out at the site. The siting was done to represent the spill site and control for background water and soil quality data. The drilling technique was percussion to ensure the exclusion of extraneous source of fluid and likely pollutants as well as to maintain minimal disturbance of soil samples retrieved for analysis.

Three (3) wells were sunk with a hand-operated light cable percussion rig to maximum depth of 15.00 to 21.00m. The wells were screened with 0.5mm slot openings, cased and capped with PVC plastic pipes (3'' diameter). The wells were also gravel packed (3/8'' gravel sizes), grouted and provided with a concrete base for proper seating of the installed casings. The were all done to prevent well collapse and groundwater contamination within the borehole sites as poor casing and/or sealing of the wells which may result in the direct ingress of contaminated surface water into the groundwater.

Soil samples were recovered at intervals from the boreholes where distinct changes in soil type occur for laboratory analysis of textural characteristics, classification and infiltration properties. The physical properties of the soil samples recovered from the boreholes were examined to obtain parameters used as indices of the infiltration capacity of the soils at the site.

Laboratory tests were carried out on representative soil samples in accordance with British Standards (B.S) 1377 which are equivalent to the ASTM (1979) Standards. The tests were grain size distribution analysis, permeability (using the constant head permeameter) and Atterberg (Consistency) limits. These tests were conducted to enable the evaluation of the gradation, hydraulic conductivity (water absorbing and adsorbing ability) properties of the soil samples, as well as their classification.

Field measurements of static water levels in the boreholes were utilized in computing the hydraulic gradient (slope of water table) between the boreholes. This was deduced from the relationship:

Hydraulic gradient (i) = Hydraulic head loss (m)/Horizontal distance between boreholes (m) $= (h_1 – h_2) / 1$

Where h_1 = Water level at borehole 1
h_2 = Water level at borehole 2
1 = Horizontal distance between BH1 and BH 2.

RESULTS AND DISCUSSION

Soil Stratigraphy and Physical Properties

The lithostratigraphic correlation is shown in Figure 2. The results reveal a uniform correlation in the three (3) boreholes of medium to very coarse grained sand and gravelly sand. The lower layers are coarser, so that there appears to be a downward coarseness of the grains. There is also a downward decrease in the shade of brownish colour. In BH 1, there is an upper stratum of dark brown, medium grained, friable sand to a depth of about 9.00m. This is underlain by light brown, very coarse grained, gravelly sand. BH 2 and BH 3 display similar profiles of overlying dark brown, medium grained, friable sands of about 3.0m in thickness. This is followed by light brown, coarse grained sands to depths of about 15.00m. Light brown, very coarse grained, gravelly sands extend from this depth to the maximum drilled depth of 21.00m.

The result of this study reveals that the soil is non-plastic and falls within the soil classification group of SP under the Unified Soil Classification System. Permeability tests of the samples recorded moderately high values as expected for the sandy soils and range from 7.83×10^{-1}cm/s to 8.92×10^{-1}cm/s. The hydraulic gradient between BH 1 and BH 3 is about 6% or 1m in 16m (1:16) while that between BH 1 and BH 2 is about 7% or 1m in 14m (1:14).

The physical properties of the soil samples recovered from the boreholes were examined to obtain parameters used as indices of the infiltration capacity of the soils in the area. The summary of the laboratory test results are presented in Table 1.

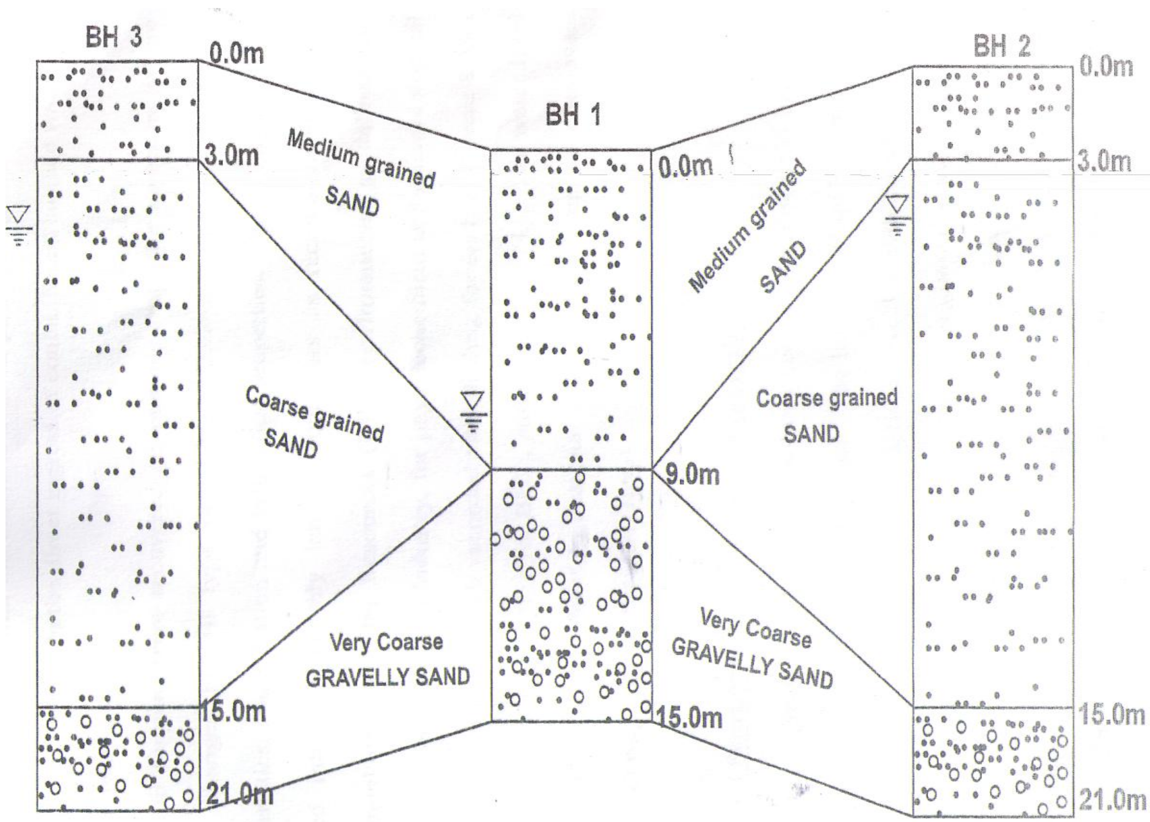

Figure 2. Lithostratigraphic Correlation of Boreholes in the Area

Table 1. Summary of Laboratory Test Results

BH No.	Sample Number	Depth (m)	Soil Nomenclature	Grain Size Distribution (Percent Passing Sieves)				Consistency Limits			Permeability (cm/Sec)	Unified Soil Classification System (U.S.C.S)
				No.4(4.75mm)	No.10 (2.0mm)	No.40(0.42mm)	No.200(0.075mm)	LL(%)	PL(%)	PI(%)		
BH1	BH1 (0m)	0.0	SAND	97.70	95.00	48.30	10.00	-	-	Non Plastic	8.1×10^{-1}	SP
	BH1 (15m)	15.0	GRAVELLY SAND	97.30	83.30	8.70	0.30	-	-	Non Plastic	8.90×10^{-1}	SP
BH2	BH2(1m)	1.0	SAND	100	99.30	38.60	16.30	-	-	Non Plastic	7.86×10^{-1}	SP
	BH2(9m)	9.0	SAND	100	99.00	39.40	14.40	-	-	Non Plastic	7.92×10^{-1}	SP
	BH2(21m)	21.0	GRAVELLY SAND	97.70	87.40	13.10	0.40	-	-	Non Plastic	8.92×10^{-1}	SP
BH3	BH3(1m)	1.0	SAND	99.70	97.30	43.60	19.60	-	-	Non Plastic	7.83×10^{-1}	SP
	BH3(3m)	3.0	SAND	100	100	21.60	0.90	-	-	Non Plastic	8.32×10^{-1}	SP
	BH3(21m)	21.0	GRAVELLY SAND	92.00	89.70	29.70	0.70	-	-	Non Plastic	8.87×10^{-1}	SP

Results of the grain size analysis show from the data and uniform gradation a range of poorly graded sands and gravelly sands with little or no fines (0.30 - 19.60% passing 0.075mm sieve. The coarse-grained nature of the sands means that fluid flow through them may be rapid, as the number of particles per unit area is relatively large and void spaces are greater. The sands are therefore highly permeable on account of its loose, coarse grains. The soil at the study area were determined to be non-plastic and fall within the soil classification group of SP under the Unified Soil Classification System (U.S.C) scheme (Table 1).

The values obtained from permeability tests of the samples were moderately high values as expected for these sandy soils and range from 7.83 x 10^{-1}cm/s to 8.92 x 10-1cm/s (Table 1). Infiltration capacity of soil depends on the permeability, degree of saturation, vegetation and amount and duration of rainfall (Todd, 1980). The ability of the sediment to hold and transmit water is determined by their porosity and permeability. Coefficient of permeability increases with increase in void sizes, which in turn increases with increasing grain size. The larger grains permit more fluid motion as a result of high permeability than the finer ones. Permeability depends on soil density, degree of saturation, viscosity of fluid, and soil particle size.

Hydrological Conditions and Pollution Sensitivity

Despite the moderately high annual rainfall (annual average over 200mm), shortage of water presents a major problem in the study area. The high permeability of the strata allows rainwater to infiltrate to great depths. Consequently, there are no perennial streams and practically no run-off. The dry land is also not affected by seasonal floods, hence is marked by good drainage conditions. Marshes have shown that the main body of groundwater in the region is contained in very thick and extensive sand and gravel aquifers of the Benin Formation. Its huge outcrop area and coarse texture is known to constitute a very good groundwater aquifer. As a result of the free draining nature (high permeability) of the soils in the study area, horizontal and vertical flow of effluents into the subsurface is high (Boonstra, 1989). This is evident in the high degree of crude oil contamination of the groundwater, particularly within the region of the waste pit.

The hydraulic gradient between BH 1 and BH 3 is about 6% or 1m in 16m (1:16) while that between BH 1 and BH 2 is about 7% or 1m in 14m (1:14). Since the hydraulic gradient between BH1 and BH 2 is slightly higher, more rapid effluent discharge is expected towards BH 1 in that direction. This may explain the higher concentration of crude oil contamination in BH 1.

CONCLUSION

This study reveals that the lithostratigraphic units of the boreholes in the area have free draining sands and gravelly sands. This supports the high degree of groundwater contamination from hydrocarbon discharges. The aquifer is also determined to have a high permeability potential, which aid lateral and vertical flow of effluents into the subsurface. This, the study reveals, is responsible for the high degree of crude oil contamination of the groundwater in the waste pit in the flowstation. The geo-environmental monitoring plan, as revealed in this study has aided in the better understanding of the importance of Environmental Impact Assessment.

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